Prediction of Rotor-Blade Deformations Due to Unsteady Airloads

Prof. Dr.-Ing. J. Ballmann

Dr.-Ing. S. Schlechtriem

N6817194C9068

R&D 7213-AN-01

1st Interim Report

May 1994 - June 1995

~~The Research reported in this document has been made possible through the support and sponsorship of the U.S. Government through its European Research Office of the U.S. Army. This report is intended only for the internal management use of the Contractor and U.S. Government.~~

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
JULY, 31, 1994

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
Prediction of Rotor-Blade Deformations Due to Unsteady Airloads

5. FUNDING NUMBERS

6. AUTHOR(S)
Stefan Schlechtriem
Josef Ballmann

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Lehr- und Forschungsgebiet für Mechanik
RWTH Aachen , Templergraben 64
D-52062 Aachen
GERMANY

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
European Research Office
USARDSG - UK
223 Old Marylebone Road
London NW1 5th , United Kingdom

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release, Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
SOFIA, a computer code for aeroelastic computations, was applied to predict the rotor blade deformations due to unsteady airloads caused by BVI and to investigate appropriate control movements to minimize vibration and noise. The computation of the unsteady, compressible, inviscid flow about rotor-blades uses an Euler CFD code, while a quasi one-dimensional structural solver is used to compute the deformation of the rotor blades.

14. SUBJECT TERMS
BVI, individual blade control, aeroelasticity, unsteady airloads, Euler CFD code, Timoshenko-beam theory

15. NUMBER OF PAGES
7

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Table of Contents

1st Interim Report

Chapter

1. Introduction

The prediction of rotor blade deformations due to unsteady airloads requires on one hand the accurate treatment of the blade-vortex interaction and on the other hand the proper computation of the elastic deformation of the blade.
In chapter 2 an overview of the actual structural data which will be used during the remaining research project is included. Chapter 3 deals mainly with the verification of the CFD code. A comparison of experimental data obtained at NASA Ames 80 by 120 Foot Wind Tunnel with results from the Euler code is given. Chapter 5 summarizes the remaining research programme.

2. Verification of the structural data and validation of the structural model

In addition to solving the structural differential equations using a characteristic method /1/ a FEM method has been developed based on TIMOSHENKO and FLÜGGE theory also. Various comparisons have been carried out to validate the method (see Figure1). In Figure 1 deviations of the EULER-BERNOULLI theory from TIMOSHENKO-FLÜGGE beam theory are obvious, especially at higher harmonics.
During the first period of the research programme an investigation concerning the material properties of the rotor blade was carried out. Experimental data from MBB, FEM computations of other authors and our own results has been reviewed. The relevant material properties of a BO105 blade like density, stiffnesses (torsional, bending), moments of inertia as well as center of gravity, elastic center and bending center is now available at the institute and will be included in the final report. The stress wave velocities follow immediately from the above mentioned data.

3. Verification of the CFD code

An experimental study of rotor blade-vortex interaction (BVI) aerodynamics and acoustics was carried out by F.X. Caradonna /2/ at NASA Ames. The vortex was generated externally and interacts with the two-bladed rotor at zero thrust. During the BVI several propagative and convective events occur and the ability to predict these events is a good accuracy test for a CFD method. Figure 2 shows the experimental blade pressure variations induced by BVI and the comparison with our computations. The results are very promising and all the important flow features especially the "trailing edge wave" (our terminology) or "secondary BVI wave" (Caradonna´s terminology) are captured.
Two-dimensional investigations have been performed to study various parameters (e.g. center of elasticity, stiffness, etc.). Figures 3 show some typical results. The whole unsteady data have been analyzed and put on video. The acoustic wave propagation phenomena are enlightend and the effect of the elastic deformation on the transient pressure field can be seen.

/1/ S. Schlechtriem, D. Nellessen, J. Ballmann: "Elastic Deformation of a Rotor Blade Due to BVI", paper presented at the 19th European Rotorcraft Forum, 1993, Paper No. B1

/2/ C. Kitaplioglu, F.X. Caradonna: "Aerodynamics and Acoustics of Blade-Vortex Interaction Using an Independently Generated Vortex", paper presented at the American Helicopter Aeromechanics Specialists Conference, San Francisco, 1994

4. Statement of further research plans

The remaining research programme covers the investigation of appropriate active control movements and the quantitative determination of the influence of the elastic deformation on the aerodynamic loads. Therefore the work to be done focuses now on the three-dimensional calculation of a blade-vortex interaction. Figure 4 shows the pressure distribution about a rotor blade at a tip Mach number of 0.8.

5. Papers submitted for publication

S. Schlechtriem, D. Nellessen, J. Ballmann: "A Numerical Investigation of the Influence of Active Control Movements on Vibration and BVI-Noise", a proposed paper for the 20th European Rotorcraft Forum

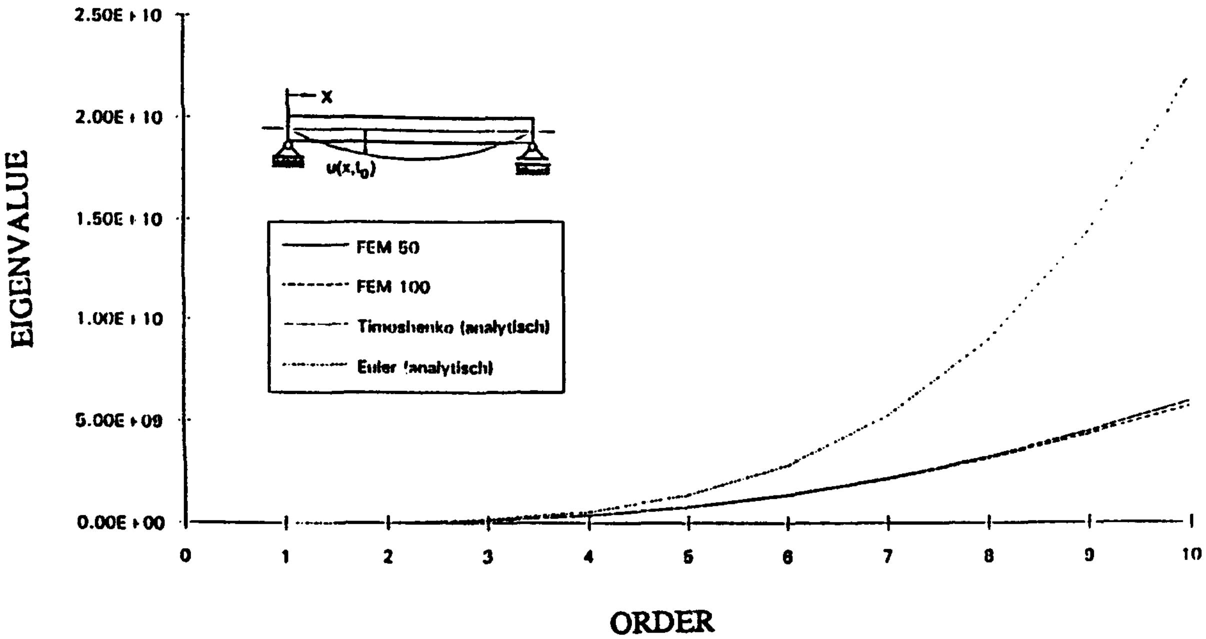
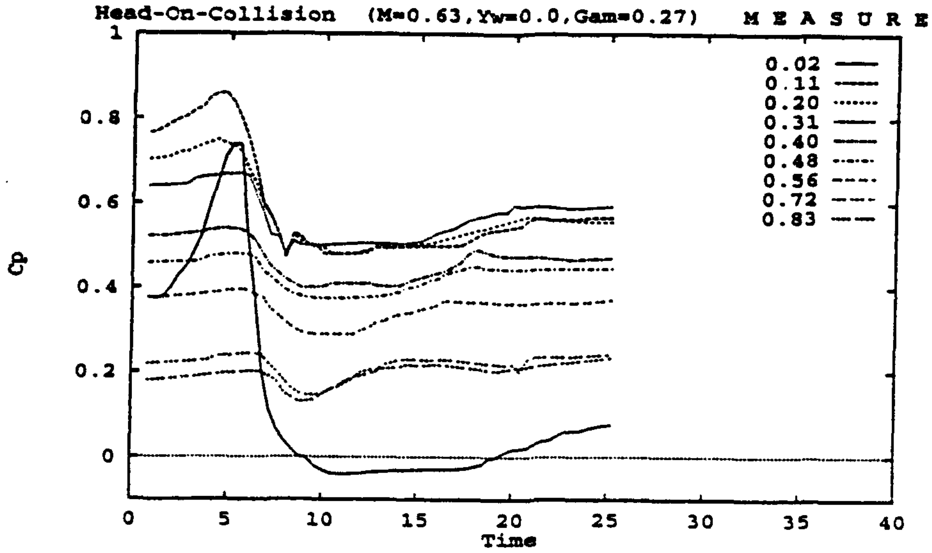
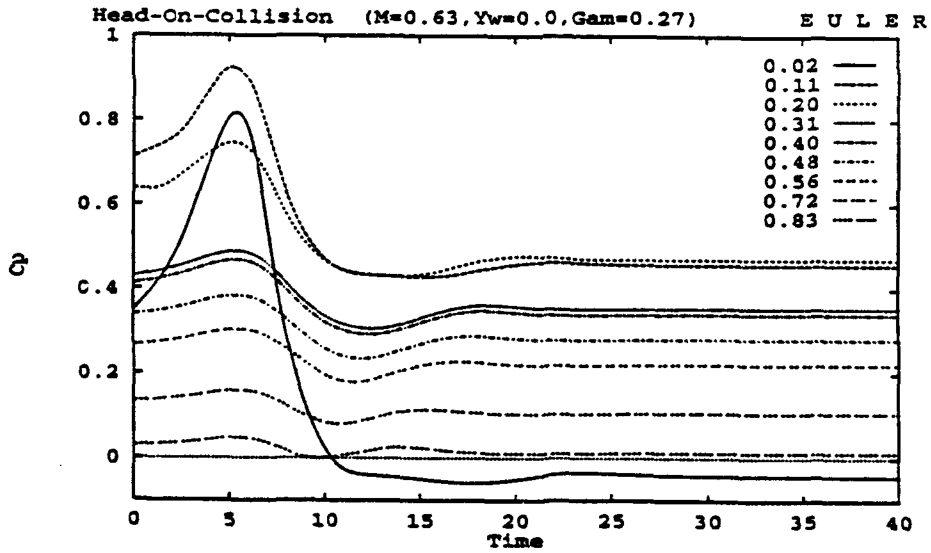


Fig. 1: Comparison between Timoshenko-Flügge und Euler-Bernoulli theory, Validation of new one-dimensional structural analysis code (ODISA)



EXPERIMENT



COMPUTATION

Fig. 2: Comparison of Caradonna's experiments with Euler computations (parallel BVI)

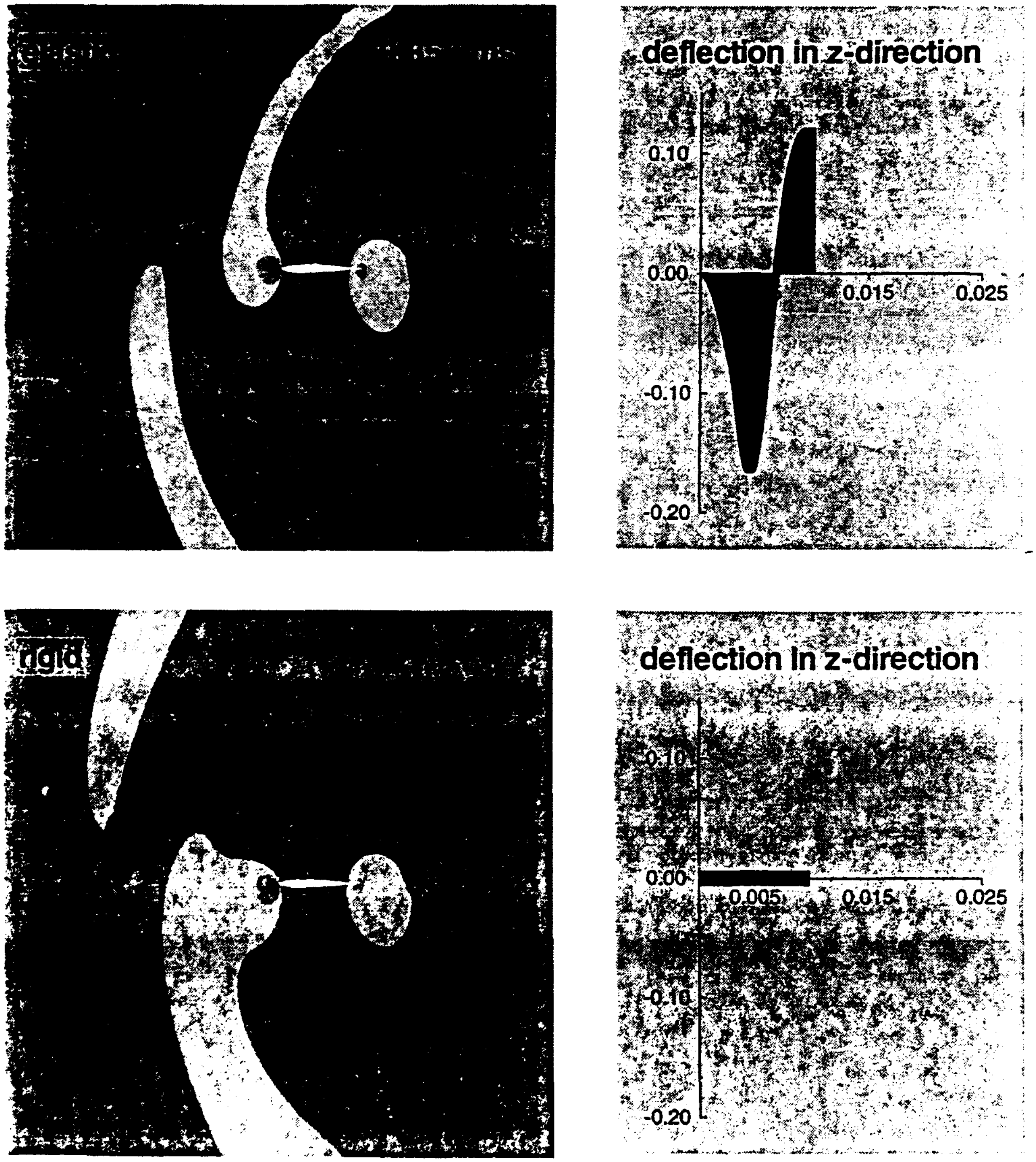


Fig.3a: Typical results of a BVI computation (rigid versus flexible blade, 1DOF: plunge)

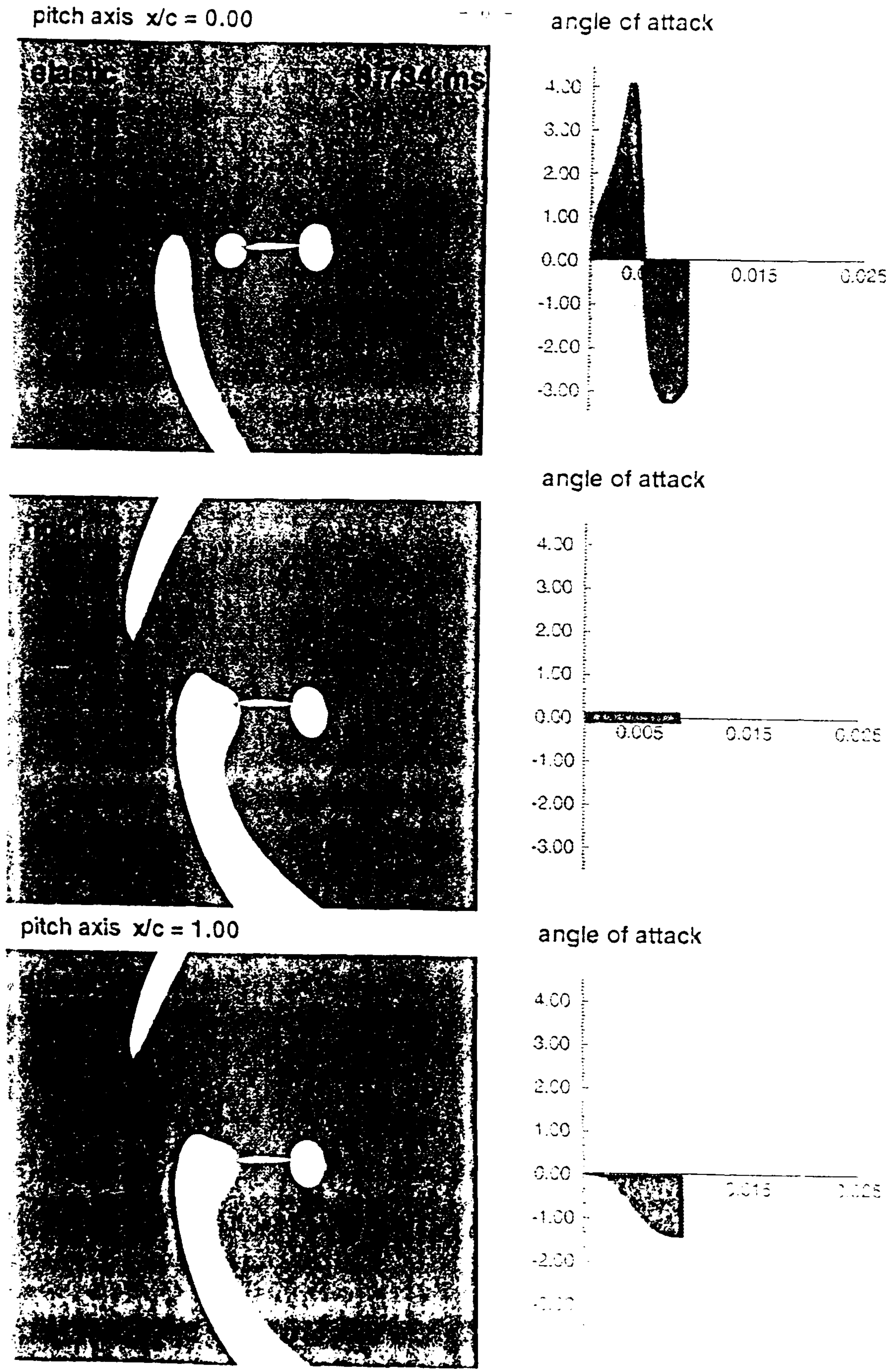


Fig.3b.: Typical results of a BVI computation (rigid versus flexible blade, 1DOF: pitch)

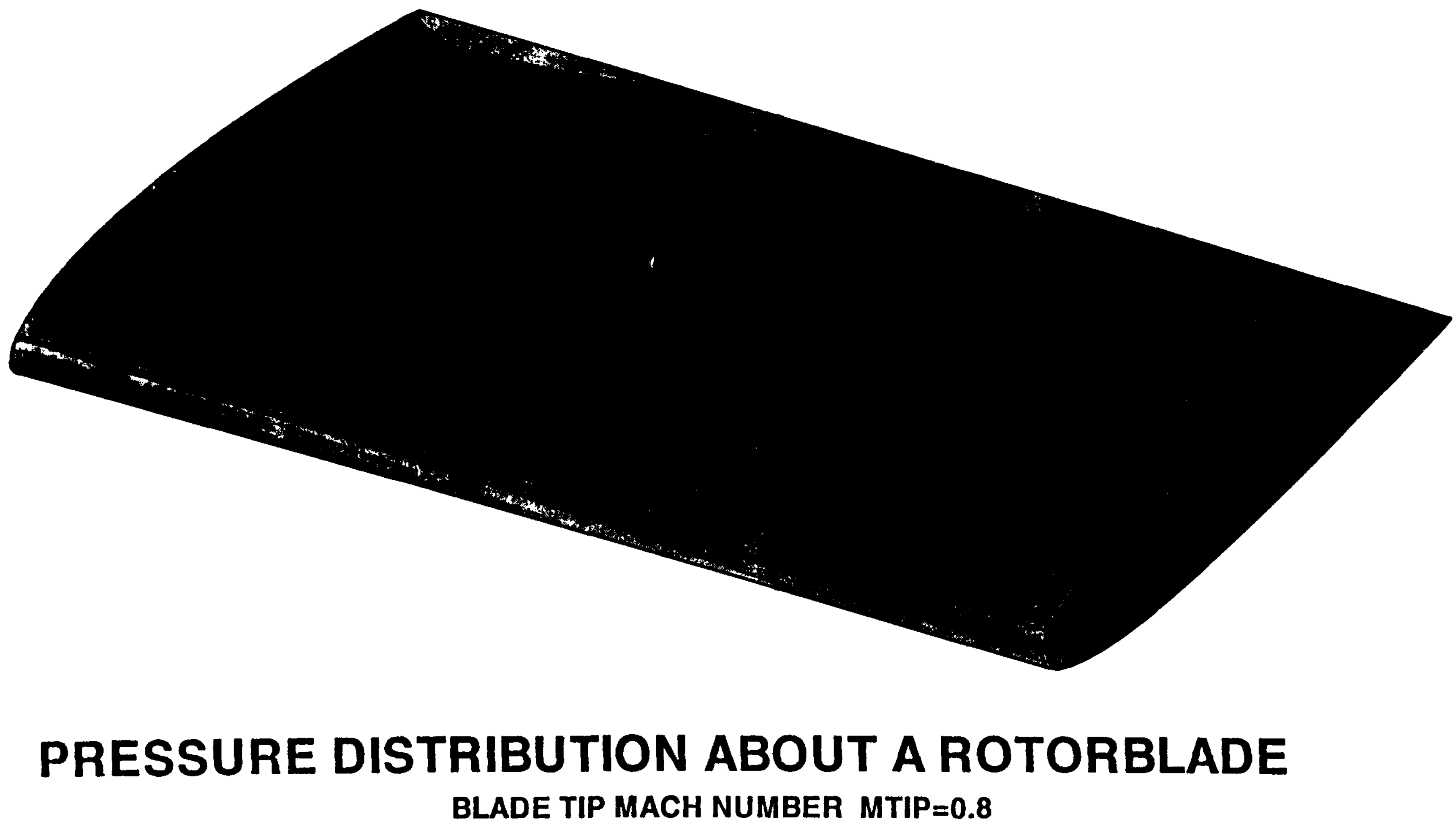


Figure 4: Sketch of the pressure distribution of a model rotor blade